United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

Research Note NE-333

1986

# Helicopter Propwash Dislodges Few Spruce Budworms

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## Abstract

Propwash treatments from a low-flying Bell 47-G2 helicopter dislodged few spruce budworm larvae and pupae from host balsam-fir trees. After propwash treatments, both larval-pupal densities on branch samples and in drop-tray collections near the ground were not significantly different between treated and control plots. Significantly more larvae were found in the lower crowns of treated trees, possibly indicating a downward shift in the larval population due to treatment. Residual parasitized larvae was 15.9 percent on treated trees and 14.6 percent on control trees.

**ODC** 413.4

Late instars of the spruce budworm, *Choristoneura fumiferana* (Clem.), the western spruce budworm, *C. occidentalis* Freeman, and the jack pine budworm, *C. pinus pinus* Freeman, drop from host trees when disturbed. Stimuli that cause larvae to drop include strong winds (Shepherd 1956), sudden flooding of larval feeding tunnels (Wellington and Henson 1947; Wellington 1948), and mechanically induced branch vibrations (Jennings 1971a). Photic reversals brought on by high temperatures or by starvation also result in larvae dropping to lower crown levels or to the ground (Wellington 1948). Larvae of the spruce budworm are most active and susceptible to dropping when temperatures and evaporation rates are high (Wellington 1948).

Once on the ground, larvae of coniferophagous budworms attempt to regain tree crowns by climbing. However, many are lost because the larvae climb nonhost vegetation and starve, or are attacked by predators. Outside their feeding shelters, larvae are exposed to predators such as ants, spiders, and carabid beetles. Six species of ants preyed on late instars of the jack pine budworm after the budworms had been dislodged from their feeding sites on jack pine (Jennings 1971b).

Morris and Mott (1963) indicated that an undisclosed proportion of spruce budworm larvae that fell to the forest floor returned back to the crowns of the same or neighboring trees. However, Batzer and Addy (1971) showed that few radioactively tagged jack-pine budworm larvae were able to regain tree crowns of jack pine, *Pinus banksiana* Lambert, even when released within 1 m of tree boles. Miller (1963) indicated that some mature larvae of the spruce budworm might pupate in the shrub layer after dropping from host trees.

If large numbers of larvae can be stimulated to drop from host trees, and if few return to tree crowns or pupate in the shrub layer, then induced-dropping behavior might be used to reduce populations. Jennings (1971a) demonstrated that larval and pupal populations of the jack pine budworm are reduced ($\bar{X} = 74$ percent) on individual trees by mechanically striking branches with long poles. Obviously, this method has limitations over large areas. We therefore sought other potential methods of stimulating dropping and postulated that the propwash from a low-flying helicopter may act as a stimulus. Wellington (1976) noted that on hot, dry afternoons, the propeller wash from low-flying aircraft caused late instars of the spruce budworm to drop.

In June 1977, we tested the effects of a low-flying helicopter on late instars (5th and 6th) and pupae of the spruce budworm in a budworm-infested forest of central Maine. This publication describes the results of our exploratory study.

## Materials and Methods

### Study Area

The helicopter propwash experiment was conducted on the Penobscot Experimental Forest near Bradley, Penobscot County, Maine. This spruce-fir-hemlock-mixed hardwood forest supported active, feeding populations of spruce budworm in 1977. Defoliation was first noticeable on the forest in 1976. The study area was free of insecticidal spraying before and after propwash treatment. Four plots were established, one each in compartments C-4, C-8, C-9, and C-22. Study sites were chosen that had a high component of balsam fir, *Abies balsamea* (L.) Miller. Two plots, one each in compartments C-8 and C-22, were designated for treatment; two plots, one each in C-4 and C-9, served as controls.

Figure 1.—Bell 47-G2 helicopter used for the propwash treatments.

### Forest Stand Characteristics

Forest stand data were obtained from a series of permanent 0.02- and 0.08-ha plots maintained on each compartment. Basal areas were calculated and expressed as $m^2$/ha. Stand composition of each tree species was determined by percentage basal area. Only living trees were included in the basal-area summaries.

### Helicopter Treatments

A Bell 47-G2 helicopter[1] (Fig. 1) was used in this study. The Maine Forest Service supplied the helicopter and the pilot. Six helium-filled balloons, three each at either end of a treatment plot (long axis, Fig. 2A) marked the proposed flight path. During treatments, radio communications were maintained between ground observers and the pilot. Flight speeds were estimated by the pilot; observers on the ground estimated helicopter altitudes above treetops.

### Sample Trees

Five dominant or codominant balsam firs were selected near plot centers for sampling budworm populations after propwash treatments. Trees were flagged and numbered, and diameters at breast height (d.b.h.) were measured to the nearest centimeter.

### Larval-Pupal Density

Sample tree crowns were divided visually into thirds; three branches were cut from the upper level, two from the middle level, and two from the lower level. The branches, each about 45 cm long, were cut with an extendable pole pruner equipped with a clamping device (Stein 1969). Care was taken not to disturb resident larvae or pupae. Cut branches were lowered or dropped onto ground cloths; all disturbed, dislodged larvae and pupae were collected and included with each branch sample. Once on the ground, branches were measured (cm) for maximum length and width, and branch surface areas (A) calculated by the formula: $A = \text{length} \times \text{width}/2$ (Sanders 1980). Branch sampling for control and treated plots was completed between 1 p.m. and 6:30 p.m. (EDT) of the same treatment day.

Branches were placed in plastic bags and transported to the laboratory for examination. All larvae and pupae of the spruce budworm were identified, removed, and counted. Population densities were expressed as mean larvae and pupae/$m^2$ of foliage area.

### Defoliation

Following methods and procedures similar to Ashley and Stark (1976), we estimated budworm defoliation on each branch sample by assigning new shoots to one of four classes: 0, less than 30, 31 to 70, and 71 to 100. A weighted percentage defoliation was calculated for each branch, and weighted mean percentages calculated for plots and for treatments by crown level.

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[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture, the Forest Service, or the University of Maine of any product or service to the exclusion of others that may be suitable.

## Drop Trays

To collect dropping larvae and pupae, drop trays (1.2 m × 1.2 m × 8 cm) were constructed from hardboard and wood strapping (Fig. 3). Each tray was lined with plastic sheeting for water retention.

For treated plots, three trays were placed 20 m apart along a line transect; two additional trays were placed at right angles, 7 m from the center tray (Fig. 2A). This arrangement allowed the collection of larvae and pupae dislodged by the propwash from an over-flying helicopter with a 10.7-m rotor blade. For control plots, three trays were placed 20 m apart along a line transect (Fig. 2B).

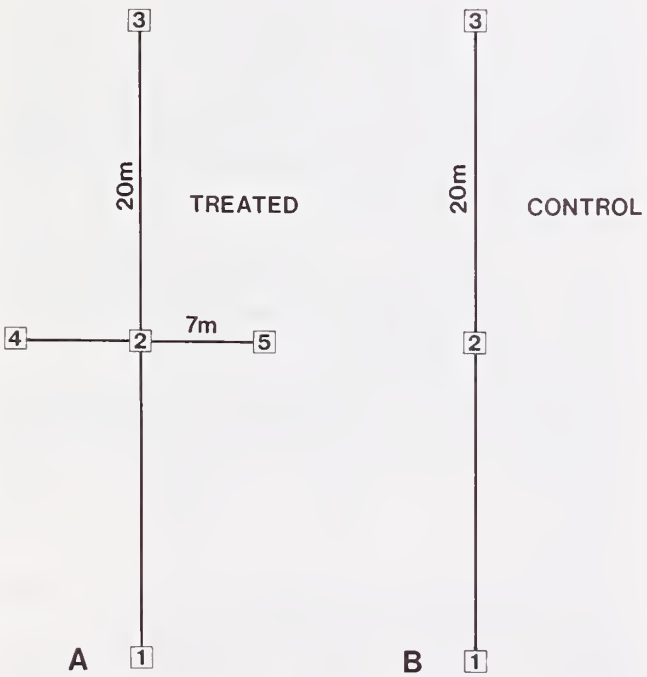


Figure 2.—Schematic of drop-tray layouts: treated plots (A), control plots (B).

After placement in the forest, each tray was leveled and filled with 20 to 25 liters of water. A few drops of household detergent were added to reduce surface tension. A preliminary test indicated that falling spruce budworm larvae readily broke through the water's surface and became submerged.

To estimate natural dropping, control-plot trays were filled with water on June 14, 1977, and left undisturbed overnight. Trays were examined the following morning and emptied of all larvae and pupae before the helicopter experiment. Both treatment- and control-plot trays contained water and detergent immediately

Figure 3.—Drop tray for collecting spruce budworm larvae and pupae falling to the ground.

before treatments on June 15, 1977. About 4 hours after treatment, all trays were examined; spruce budworm larvae and pupae were removed and stored in 2-dram vials containing 70 percent ethanol.

## Parasitism

Because parasitized larvae generally are less active than nonparasitized larvae, we hypothesized that parasitized larvae would be less susceptible to dislodgment from host trees. To test this hypothesis, we compared percentages of residual parasitized larvae among control and treated plots after the propwash treatments. We dissected spruce budworm larvae for internal parasites with a stereomicroscope and dissecting needles. Parasite larvae were identified as *Apanteles* sp. or *Glypta* sp. based on drawings and descriptions of Mason (1974) and Brown (1946). A few dipterous larvae were found but were not identified.

## Weather

Temperature data were obtained from the National Weather Service field station at the University of Maine, Orono, located 6 to 7 km northwest of the study plots. Wind velocity and directional data were obtained from the Flight Service Station, Bangor International Airport, 16 to 18 km southwest of the study plots.

## Results

### Forest Stands

Mean basal areas for study compartments ranged from 18 to 30 $m^2$/ha; control-plot mean was 22.8 $m^2$/ha, treated-plot mean was 28.6 $m^2$/ha. Basal-area percentages of balsam fir ranged from 15 to 26 among all plots. Principal budworm-host trees (balsam fir and spruces) accounted for 33 to 43 percent of the stand species; the remaining species were mostly nonhost softwoods and hardwoods.

### Sample Trees

Diameters of trees sampled for budworm populations ranged from 10 to 20 cm for control plots and from 10 to 21 cm for treated plots. None of the plot means was significantly different ($P < 0.05$) for tree diameter, and overall mean d.b.h for treated-plot trees ($\bar{X} = 14.5$) was not significantly different ($P \leq 0.05$) from control-plot trees ($\bar{X} = 15.2$).

### Helicopter Treatments

Propwash treatments, flight speeds, and estimated altitudes above treetops are summarized in Table 1. Treatments occurred between 12:40 p.m. and 1 p.m. (EDT), on June 15, 1977. Both hover treatments were 15 to 20 seconds in duration.

**Table 1.—Summary of helicopter propwash treatments, flight speeds, and altitudes above treetops, Penobscot Experimental Forest, Maine**

| Treatment | Speed | Altitude |
|---|---|---|
| | Knots | Meters |
| | PLOT C-22 | |
| Slow-low | <5 | 1.5–3.0 |
| Slow-low | <5 | 1.5–3.0 |
| Hover[a] | 0 | 1.5–3.0 |
| Fast-high | 18–20 | 6.1–7.6 |
| | PLOT C-8 | |
| Slow-low | <5 | 3.0–4.6 |
| Slow-hover[b] | 1–2 | 1.5 |
| Hover[a] | 0 | 1.5–3.0 |

[a]15–20 seconds.
[b]With forward movement.

Tree crowns and branches were shaken vigorously by the slow-low and hover treatments. A few larvae and pupae were observed in the drop trays immediately after the slow-low treatment; more larvae and pupae were observed in the trays after the hover treatment. The fast-high treatment produced no noticeable downwash, i.e., little movement of tree crowns.

### Larval-Pupal Density

Larval-pupal density did not differ significantly ($P \leq 0.05$) between treatments (Table 2). Within treatments, treated-plot means were not significantly different, though control plot C-9 had significantly fewer larvae and pupae than control plot C-4.

Larval-pupal density varied significantly ($P \leq 0.05$) by crown level. For both the treated- and control-plot trees, there were significantly more larvae and pupae in the upper crown than in the middle or lower crown (Table 3). These results agree in part with Morris (1955); larval populations tend to be higher in the top levels of balsam fir until defoliation causes a downward shift in the population.

**Table 2.—Spruce budworm larval-pupal densities/$m^2$ of foliage, by treatment,[a] Penobscot Experimental Forest, Maine**

| Plot | n | $\bar{X}/m^2$ | SE |
|---|---|---|---|
| | CONTROL | | |
| C-4 | 35 | 88.07a | 10.46 |
| C-9 | 34 | 55.68b | 7.61 |
| Overall[b] | 69 | 72.11 | 6.74 |
| | TREATED | | |
| C-8 | 35 | 62.00a | 6.55 |
| C-22 | 35 | 80.82a | 12.61 |
| Overall[b] | 70 | 71.41 | 7.12 |

[a]Means within treatments followed by same letter are not significantly different, ANOVA, Duncan's Multiple Range Test, $P \leq 0.05$.
[b]Overall means between treatments are not significantly different, ANOVA, $P \leq 0.05$.

Between treatments, larval-pupal densities were not significantly different ($P \leq 0.05$) at any crown level. In the upper crown, treated trees had more larvae and pupae than control trees, but not significantly more.

Larval-pupal densities of control trees were greater than those of treated trees in both the middle and lower crowns, but not significantly greater (Table 3).

**Table 3.—Spruce budworm larval-pupal densities/m² of foliage, by crown level and treatment[a,b]**

| Crown level | n | $\bar{X}/m^2$ | SE |
|---|---|---|---|
| | CONTROL | | |
| Upper | 29 | 93.88a | 12.42 |
| Middle | 20 | 70.84b | 9.31 |
| Lower | 20 | 41.83b | 7.71 |
| | TREATED | | |
| Upper | 30 | 105.87a | 12.70 |
| Middle | 20 | 51.74b | 8.57 |
| Lower | 20 | 39.40b | 6.16 |

[a]Means within treatments followed by same letter are not significantly different, ANOVA, Duncan's Multiple Range Test, $P \leq 0.05$.
[b]Means between treatments are not significantly different, ANOVA, $P \leq 0.05$.

Excluding pupae, larval density followed somewhat the same pattern, i.e., there were more larvae in the upper crown of both treated and control trees (Table 4). However, between treatments, there were significantly more ($P \leq 0.05$) larvae in the lower crown of treated trees than in the lower crown of control trees, possibly indicating a downward shift in the larval population due to treatment.

**Table 4.—Spruce budworm larval densities/m² of foliage, by crown level and treatment[a,b]**

| Crown level | n | $\bar{X}/m^2$ | SE |
|---|---|---|---|
| | CONTROL | | |
| Upper | 29 | 37.88ax | 6.55 |
| Middle | 20 | 28.49abx | 5.35 |
| Lower | 20 | 12.40bx | 2.34 |
| | TREATED | | |
| Upper | 30 | 44.30ax | 5.42 |
| Middle | 20 | 21.80bx | 4.47 |
| Lower | 20 | 23.58by | 4.25 |

[a]Means within treatments followed by the same letter(s) (a and b) are not significantly different, ANOVA, Duncan's Multiple Range Test, $P \leq 0.05$.
[b]Crown-level means between treatments followed by same letter (x and y) are not significantly different, ANOVA, Duncan's Multiple Range Test, $P \leq 0.05$.

### Defoliation

Mean percentage defoliation varied within treatments by crown level (Table 5); however, overall percentages between treatments were not significantly ($P \leq 0.05$) different.

### Drop-Tray Collections

Only larvae were collected in drop trays left overnight. Collections ranged from 0 to 4 larvae/tray; means were not significantly different ($P \leq 0.05$) between control plots: C-4 $\bar{X} = 2.0$ larvae/tray, C-9 $\bar{X} = 1.7$ larvae/tray, overall $\bar{X} = 1.8$ larvae/tray.

Drop-tray collections after treatments were more variable. Collected larvae ranged from 0 to 5/tray; only two pupae were collected, one each in a control- and treated-plot tray. Although mean larvae varied among plots, overall means between treatments were not significantly different ($P \leq 0.05$) (Table 6). Considering both larvae and pupae, overall means also were nonsignificant between control ($\bar{X} = 1.67$) and treated ($\bar{X} = 2.10$) plots.

### Parasitism

More than 400 spruce budworm larvae were dissected for internal parasites. The mean percentage of parasitized larvae was only slightly higher on treated-plot branches (15.9) than on control-plot branches (14.6); hence, we found no appreciable evidence that parasitized larvae were less susceptible to dislodgement and dropping than nonparasitized larvae. Combining treatments and plots, most parasitized larvae came from upper crown branches (56.9 percent), followed by middle crown branches (37.7 percent), and lower crown branches (5.4 percent). None of the treated-plot branches from the lower crown had parasitized larvae.

More than half (52.7 percent) of the parasites (n = 55) were *Apanteles* sp.; the remainder were *Glypta* sp. (18.2 percent) and undetermined species of Diptera (29.1 percent).

### Weather

Temperature during the helicopter treatments was about 25.6°C, the maximum for June 15, 1977. Wind velocity was 22.5 km/hr at 280° (WNW). Both conditions approached the optimum for dislodging larvae.

**Table 5.—Weighted mean percentage of spruce budworm defoliation, by crown level and treatment[a]**

| Plot | Upper crown | | Middle crown | | Lower crown | | All crown levels | |
|---|---|---|---|---|---|---|---|---|
| | Percent | SE | Percent | SE | Percent | SE | Percent | SE |
| | | | | CONTROL | | | | |
| C-4 | 41.0a | 9.6 | 71.4a | 3.5 | 66.1a | 8.1 | 59.5a | 5.4 |
| C-9 | 36.2a | 8.4 | 44.4b | 10.6 | 53.1a | 12.0 | 44.6a | 5.9 |
| Overall[b] | 38.6x | 6.0 | 57.9x | 6.9 | 59.6x | 7.1 | 52.0x | 4.1 |
| | | | | TREATED | | | | |
| C-8 | 23.1a | 6.5 | 33.2a | 7.6 | 34.4a | 4.0 | 30.2a | 3.6 |
| C-22 | 78.1b | 2.2 | 81.2b | 1.2 | 71.2b | 7.1 | 76.8b | 2.6 |
| Overall[b] | 50.6x | 9.7 | 57.2x | 8.8 | 52.8x | 7.3 | 53.5x | 4.8 |

[a]Mean percentages within treatments followed by the same letter are not significant, t-test, $P \leqslant 0.05$ (arcsine transformations of percentages prior to analyses.).
[b]Overall mean percentages are not significantly different, t-test, $P \leqslant 0.05$.

**Table 6.—Mean number of spruce budworm larvae and pupae collected in drop trays, by treatment, Penobscot Experimental Forest, Maine**

| Plot | n trays | Larvae | | Pupae | | Total | |
|---|---|---|---|---|---|---|---|
| | | n | SD | n | SD | n | SD |
| | | | CONTROL | | | | |
| C-4 | 3 | 2.67 | 0.58 | 0.33 | 0.58 | 3.00 | 1.00 |
| C-9 | 3 | 0.33 | 0.58 | 0.00 | 0.00 | 0.33 | 0.58 |
| Overall[a] | 6 | 1.50 | 1.38 | 0.17 | 0.41 | 1.67 | 1.63 |
| | | | TREATED | | | | |
| C-8 | 5 | 1.20 | 0.84 | 0.00 | 0.00 | 1.20 | 0.84 |
| C-22 | 5 | 2.80 | 1.48 | 1.20 | 0.45 | 3.00 | 1.22 |
| Overall[a] | 10 | 2.00 | 1.41 | 0.10 | 0.32 | 2.10 | 1.37 |

[a]Overall treated-control means are not significantly different, 1-way ANOVA, $P \leqslant 0.05$.

## Discussion

Over half of our study populations had pupated by June 15; 57 percent were pupae, 43 percent were larvae. Closer timing of the helicopter treatments with late-instar development would have been desirable. The late instars are the stages that respond most readily to disturbances by dropping. Pupae generally are immobile and usually are anchored to host-tree foliage by hooks on the pupal cremaster. Although some pupae may be dislodged, treatments should be timed to coincide with the late instars to take greatest advantage of larval dropping behavior.

The "irritability" of larvae should be determined immediately before helicopter treatment. Apparently, there are yearly variations in reactivity of larvae to disturbances (pers. comm. with Arthur Raske, Canadian Forestry Service). In some years, larvae become hypersensitive and respond violently to the slightest touch (Wellington 1976). Larval irritability and reactivity may be genetically controlled and related to previous infestation history, i.e., stands infested for numerous years and with depleted foliage may produce larvae that are more susceptible to dropping. Our study was done during the early stages of an outbreak when trees were only moderately defoliated. Selection of heavily defoliated stands where food supplies are limited may produce different results.

Atmospheric conditions should also be monitored on site to better take advantage of behavioral responses to high temperatures and high rates of evaporation (Wellington and Henson 1947). Cloud cover also is important (Wellington 1948). If possible, treatments should be done under hot and dry conditions. A larger helicopter with greater propwash velocities than the Bell 47-G2 might produce more drastic effects on larval-pupal populations of the spruce budworm.

## Acknowledgments

We thank the Maine Forest Service for supplying the Bell 47-G2 and Randall Billings for piloting the helicopter during treatments. Jeffrey C. Emery, Department of Environmental Protection, Bangor, supplied wind velocity and directional data; Fenton E. Stormann, Department of Physics, University of Maine, Orono, supplied temperature data. Richard A. Hosmer and

June M. Crawford provided computer programming assistance and Regina C. McCombs provided technical assistance.

This paper is a contribution to the Canada/United States (CANUSA) Spruce Budworms Program.

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